CONFIDENTIAL

c.1

Copy 5
RM L51E17

NACA RM L51E17

# RESEARCH MEMORANDUM

## FREE-FLIGHT-TUNNEL INVESTIGATION OF THE DYNAMIC LATERAL STABILITY AND CONTROL CHARACTERISTICS OF A HIGH-ASPECT-RATIO BOMBER MODEL WITH SELF-SUPPORTING FREE-FLOATING FUEL TANKS ATTACHED TO THE WING TIPS


By Charles V. Bennett and Robert B. Cadman

Langley Aeronautical Laboratory
Langley Field, Va.


CLASSIFICATION CHANGED

UNCLASSIFIED

FOR REFERENCE

NOT TO BE TAKEN FROM THIS ROOM

To ______________

By authority of NACA Res abs effective RN-127 Date May 16, 1958

amt 6-13-58




NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON
August 7, 1951


CONFIDENTIAL

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

# FREE-FLIGHT-TUNNEL INVESTIGATION OF THE DYNAMIC LATERAL STABILITY AND CONTROL CHARACTERISTICS OF A HIGH-ASPECT-RATIO BOMBER MODEL WITH SELF-SUPPORTING FREE-FLOATING FUEL TANKS ATTACHED TO THE WING TIPS

By Charles V. Bennett and Robert B. Cadman

## SUMMARY

An experimental investigation has been made in the Langley free-flight tunnel to determine the dynamic lateral stability and control characteristics of a high-aspect-ratio bomber model with self-supporting, free-floating fuel tanks attached to the wing tips. This arrangement represents a configuration in which an auxiliary fuel supply could be efficiently carried without the large increase in wing bending moments normally encountered with fixed wing-tip tanks. Full-span flaps on the lifting surface of the tanks operate automatically in response to the relative bank angle between the bomber and tanks to keep the tanks alined with the bomber wing. The effect of a variation in restoring moment on the flying characteristics of the model was determined in the investigation by varying the gearing ratio (ratio of floating tank flap angle to angle of bank of the tank with respect to the bomber) and the size of the flap.

The results of the investigation showed that the flight behavior of the configuration could be made satisfactory when sufficient restoring moment was supplied. When the restoring moment was insufficient there was considerable flapping of the tanks with respect to the bomber. These flapping motions were most noticeable after a gust or control disturbance and the random disturbances caused by the flapping made it almost impossible for the pilot to maintain smooth wing-level flight.

[redacted]

## INTRODUCTION

It has been proposed that the range of bomber airplanes be increased by the addition of auxiliary fuel supplies in free-floating fuel tanks hinged to the bomber wing tips. The weight of the auxiliary fuel would be supported by lifting surfaces on the fuel tanks so that there would be essentially no increase in wing loading and, because of the increased aspect ratio, the auxiliary fuel supply probably could be carried more efficiently in this manner than by any other means. By hinging the fuel tanks to the wing with freedom in roll the wing bending loads caused by the aerodynamic and mass forces on the tanks could be minimized.

Investigations have been made in the Langley free-flight tunnel to determine the lateral stability and control characteristics of various floating tip configurations. Reference 1 contains the results of an investigation made to determine the lateral stability and control characteristics of an aspect-ratio-5.06 model having self-supporting, fuel-carrying panels hinged to the wing tips and reference 2 contains the results of an investigation of another low-aspect-ratio model with simplified fighter models attached to the wing tips with one, two, or three degrees of angular freedom. In order to extend this work to include higher-aspect-ratio models, the lateral stability and control characteristics of an aspect-ratio-10.76 model with free-floating fuel tanks hinged at the tips were determined by an experimental investigation in the Langley free-flight tunnel. The results of this investigation are presented herein. The tanks were weighted to simulate a fuel load and full-span flaps on the lifting surface of the tanks were automatically operated in response to the relative bank angle between the floating tanks and the model to keep the tanks alined with the bomber wing. The investigation consisted of flight tests of the bomber model alone and with the tanks attached rigidly and with freedom in roll with respect to the bomber.

## APPARATUS AND TESTS

The investigation was conducted in the Langley free-flight tunnel which is described in reference 3. A sketch of the model with the free-floating wing tanks attached is shown in figure 1. The dimensional and mass characteristics of the bomber model and free-floating tanks are given in table I. All tests were made at a dynamic pressure of approximately 4.25 pounds per square foot which corresponds to a lift coefficient of 0.88 for the bomber alone. A slat (fig. 1) was installed on the bomber model wing to delay premature wing-tip stalling which was attributed to the low scale (Reynolds number of approximately 55,000) at which the tests were conducted. The lifting surfaces of the free-floating tanks were equipped with full-span flaps of 20 percent chord. The flap effectiveness was increased for some tests by adding 3/16- and 3/8-inch extensions to the trailing edge of the full-span flaps. These extensions increased the chord of the flaps by 56 and 112 percent, respectively.

The free-floating tanks were attached to the bomber by means of a hinge which provided freedom in roll of the tanks with respect to the bomber. The weight of the tanks was adjusted so that they tended to remain alined with the bomber. The wing loading of the weighted tanks was approximately equal to the wing loading of the bomber. (See table I.)

A mechanical linkage (see fig. 2) was installed on the floating tanks to deflect the full-span flaps of the tanks in response to the relative bank angle between the bomber and tanks. With this linkage on the model, gearing ratios (ratio of tank flap angle to bank angle of tank with respect to the bomber) of 3.33 and 4.75 were obtained. Cushioning springs were installed in the linkage system to permit the tanks to roll with respect to the bomber after the maximum flap deflection of the tanks was reached. The purpose of the linked flaps was to minimize the rolling motion of the tanks relative to the bomber by producing aerodynamic forces on the tanks which tended to keep them alined with the bomber. For instance, as a tank rotated up, the flap went up and the lift on the tank was reduced, and, therefore the tank tended to return to its trimmed position.

The restoring moments about the rolling hinge produced by the linked flaps are shown in figure 3. The maximum flap deflection of $\pm 40^{\circ}$ produced a restoring moment of 0.045 foot pounds. Increasing the flap chord by 56 and 112 percent increased the aerodynamic moment by 15 and 29 percent. The vertical portion of the restoring moment curves (fig. 3) represents the preload in the cushioning springs that must be overcome before the tanks can bank to an angle greater than that which corresponds to $40^{\circ}$ flap deflection. After the preload is overcome the tanks can reach higher angles by compressing the cushioning springs. The restoring moments provided by compression of the springs are shown by the constant slope above the vertical portion of the curve. The maximum angle of bank that could be reached by the tanks (springs fully compressed) was approximately $32^{\circ}$.

Flight tests were made of the bomber alone and of the bomber with the tanks attached rigidly and with freedom in roll. In the flight tests made with the tanks attached with freedom in roll with respect to the bomber, the pilot paid particular attention to the flapping of the tanks (rolling motion of the tanks with respect to the bomber) and to the effects of this flapping on the general flight behavior of the coupled configuration. In addition, the flapping motions of the tanks were determined quantitatively from motion-picture records taken with a camera located to the rear of the tunnel test section.

## RESULTS AND DISCUSSION

The flight behavior of the bomber alone was considered representative of that of an airplane having good stability and control characteristics. The general flight behavior of the bomber with the tanks attached rigidly (which was used as a basis for comparison with that of the bomber with the tanks attached with freedom in roll) was less satisfactory than that of the bomber alone because of the slower response to aileron control and because of the decreased lateral stability. The rolling in response to a given aileron control was slower than that of the bomber alone because of the increased rolling inertia and the increased damping in roll. The decreased lateral stability apparently resulted from the increased rolling and yawing inertia. These results are similar to those reported in references 1 and 2.

The rolling motions of the bomber in controlled flight and the corresponding angles of bank of the floating tanks (measured with respect to the horizontal) are shown in figures 4 and 5. Since the film records were read within an accuracy of $\pm 0.5^{\circ}$ and no attempt was made to fair smooth curves through the scatter of points, any abrupt motion falling within these limits may not represent the actual motions of the floating tank models. In some cases the floating-tank rolling motions are displaced from those of the bomber because no attempt was made to trim the tanks to exactly zero bank with respect to the bomber. It was also difficult to keep the tanks trimmed so that the flaps were at $0^{\circ}$ deflection when the tanks were at $0^{\circ}$ bank. The data of figure 3, therefore, cannot be used to obtain accurate estimates of the restoring moments for a given condition. These data can be used, however, to obtain a general indication of the variation of restoring moment with tank bank angle for the various gearings used in the tests.

The motions of the bomber and the corresponding motions of the attached tanks are shown in figure 4 for a gearing ratio of 3.33. Flights could not be maintained without extensions on the flaps because of erratic flapping of the tanks and, therefore, no film records were obtained. The flight records of figures 4(a) and 4(b) are for a gearing ratio of 3.33 with the flap chord increased 56 and 112 percent, respectively. These records show that the flapping was reduced as the size of the extension was increased. With the flap chord increased 56 percent there was considerable flapping of the tanks with respect to the bomber. These flapping motions, which were most noticeable after a gust or control disturbance, were very lightly damped and the random disturbances caused by this erratic flapping of the tanks made it almost impossible for the pilot to maintain smooth wing-level flight. With the flap chord increased 112 percent, the flapping, although reduced, was still considered objectionable by the pilot.

The flight records for the increased gearing ratio of 4.75 are shown in figure 5. The flight records of figure 5(a) are for a gearing ratio of 4.75 without the flap extension and the records of figure 5(b) and 5(c) were obtained with the flap chord increased 56 and 112 percent, respectively. These records show that the flapping was reduced as the size of the extensions was increased. It was the pilot's opinion that the flight behavior for the condition without the flap extension was comparable to that with a gearing ratio of 3.33 with the flap chord increased 56 percent and that the condition with the flap chord increased 56 percent was comparable to that with a gearing ratio of 3.33 with the flap chord increased 112 percent.

With the gearing ratio of 4.75 and with the 112-percent flap extension, the flying characteristics were considered to be satisfactory and it was the opinion of the pilot that the flight behavior compared favorably with that for the configuration in which the tanks were attached rigidly to the bomber.

## CONCLUDING REMARKS

The results of an investigation made in the Langley free-flight tunnel to determine the dynamic lateral stability and control characteristics of a high-aspect-ratio bomber model with free-floating fuel tanks hinged at the tips indicate that the flight behavior of the configuration could be made satisfactory when sufficient restoring moment was supplied. When insufficient restoring moment was supplied there was considerable flapping of the tanks with respect to the bomber. These flapping motions were most noticeable after a gust or control disturbance and the random disturbances caused by this flapping made it almost impossible for the pilot to maintain smooth, wing-level flight.

Langley Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Field, Va.

REFERENCES

1. Shanks, Robert E., and Grana, David C.: Flight Tests of a Model Having Self-Supporting Fuel-Carrying Panels Hinged to the Wing Tips. NACA RM L9I07a, 1949.

2. Bennett, Charles V., and Cadman, Robert B.: Free-Flight-Tunnel Investigation of the Dynamic Lateral Stability and Control Characteristics of a Tip-to-Tip Bomber-Fighter Coupled Airplane Configuration. NACA RM L51A12, 1951.

3. Shortal, Joseph A., and Osterhout, Clayton J.: Preliminary Stability and Control Tests on the NACA Free-Flight Wind Tunnel and Correlation with Full-Scale Flight Tests. NACA TN 810, 1941.

TABLE I

DIMENSIONAL AND MASS CHARACTERISTICS

| | Bomber model | One floating tank model | Coupled configuration |
|---|---|---|---|
| Weight, lb | 4.87 | 0.41 | 5.69 |
| Wing loading, $lb/ft^2$ | 3.74 | 3.95 | 3.77 |
| Radius of gyration about longitudinal body axis, spans | 0.15 | ---- | [a]0.27 |
| Radius of gyration about vertical body axis, spans | 0.21 | ---- | [a]0.30 |
| **Wing:** | | | |
| Airfoil section | Rhode St. Genese-35 | Rhode St. Genese-35 | ---- |
| Span, in. | 45.00 | 9.00 | [b]63.80 |
| Area, sq in. | 187.20 | 14.94 | 217.08 |
| Aspect ratio | 10.76 | 5.42 | ---- |
| Taper ratio | 0.25 | 1.00 | ---- |
| Mean aerodynamic chord, in. | 4.66 | 1.66 | ---- |
| **Aileron:** | | | |
| Area, percent wing area (one aileron) | 3.77 | ---- | ---- |
| Chord, percent wing chord | 30.00 | ---- | ---- |
| Span, percent wing span (one aileron) | 17.92 | ---- | ---- |
| **Flap:** | | | |
| Area, percent wing area | ---- | 20.00 | ---- |
| Chord, percent wing chord | ---- | 20.00 | ---- |
| Span, percent wing span | ---- | 100.00 | ---- |
| **Fuselage:** | | | |
| Length, in. | 32.60 | 9.00 | ---- |
| Diameter, in. | 2.50 | 0.90 | ---- |
| Fineness ratio (Length/Diameter) | 13.04 | 10.00 | ---- |
| **Vertical tail:** | | | |
| Airfoil section | NACA 0012 | ---- | ---- |
| Span, in. | 6.31 | ---- | ---- |
| Area, percent wing area | 13.50 | ---- | ---- |
| Aspect ratio | 1.58 | ---- | ---- |
| Taper ratio | 0.33 | ---- | ---- |
| **Horizontal tail:** | | | |
| Airfoil section | NACA 0009 | ---- | ---- |
| Span, in. | 15.00 | 4.00 | ---- |
| Area, percent wing area | 22.09 | 21.42 | ---- |
| Aspect ratio | 5.50 | 5.00 | ---- |
| Taper ratio | 0.38 | 0.60 | ---- |
| Tail length $\frac{1}{4}$-chord of wing mean aerodynamic chord to rudder hinge line, in. | 15.47 | ---- | ---- |

[a]Based on span of bomber.
[b]Includes gap for hinge installation.

NACA

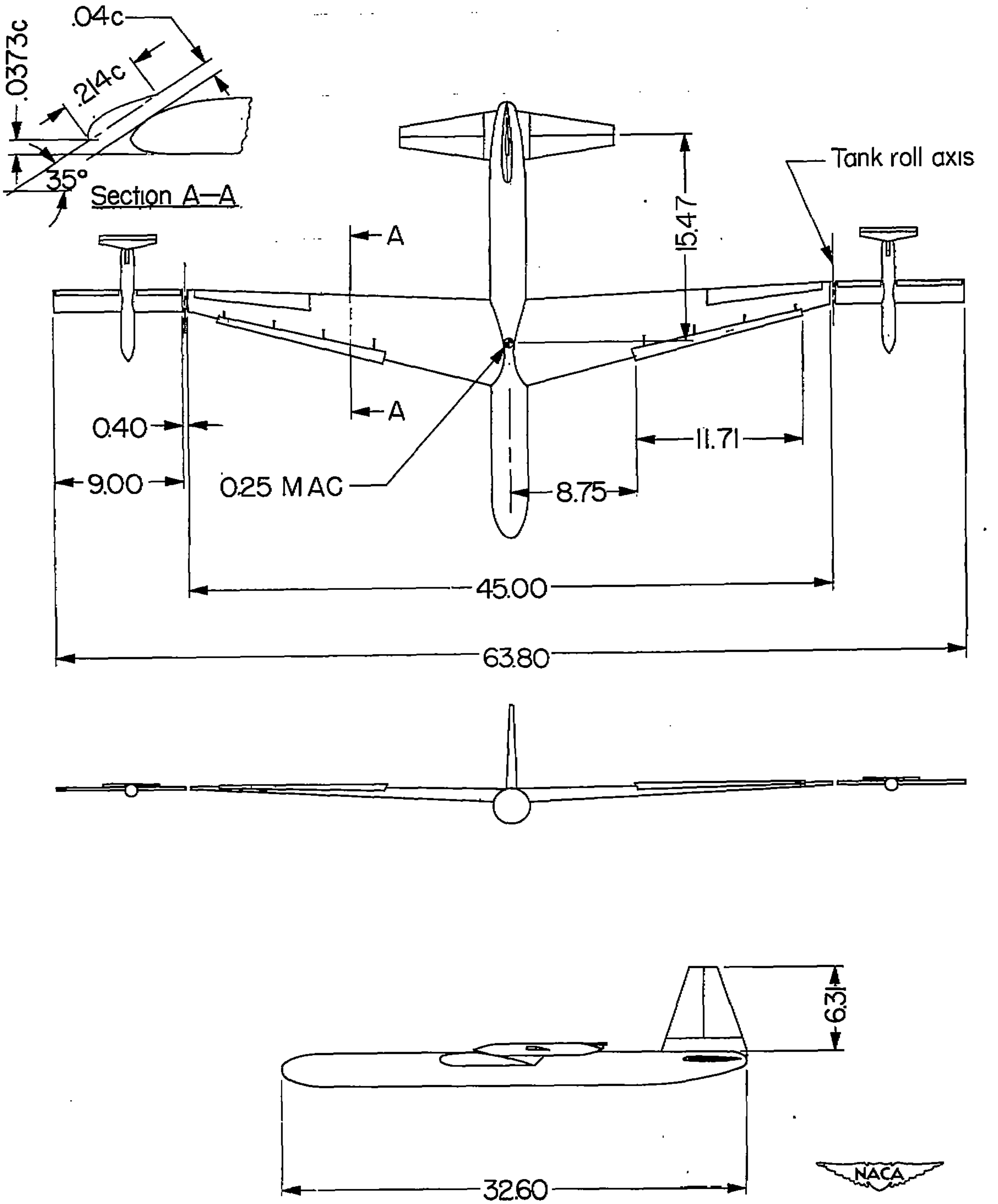


Figure 1.- Three-view sketch of high-aspect-ratio bomber model with free-floating fuel tanks installed. All dimensions are in inches.

[redacted]

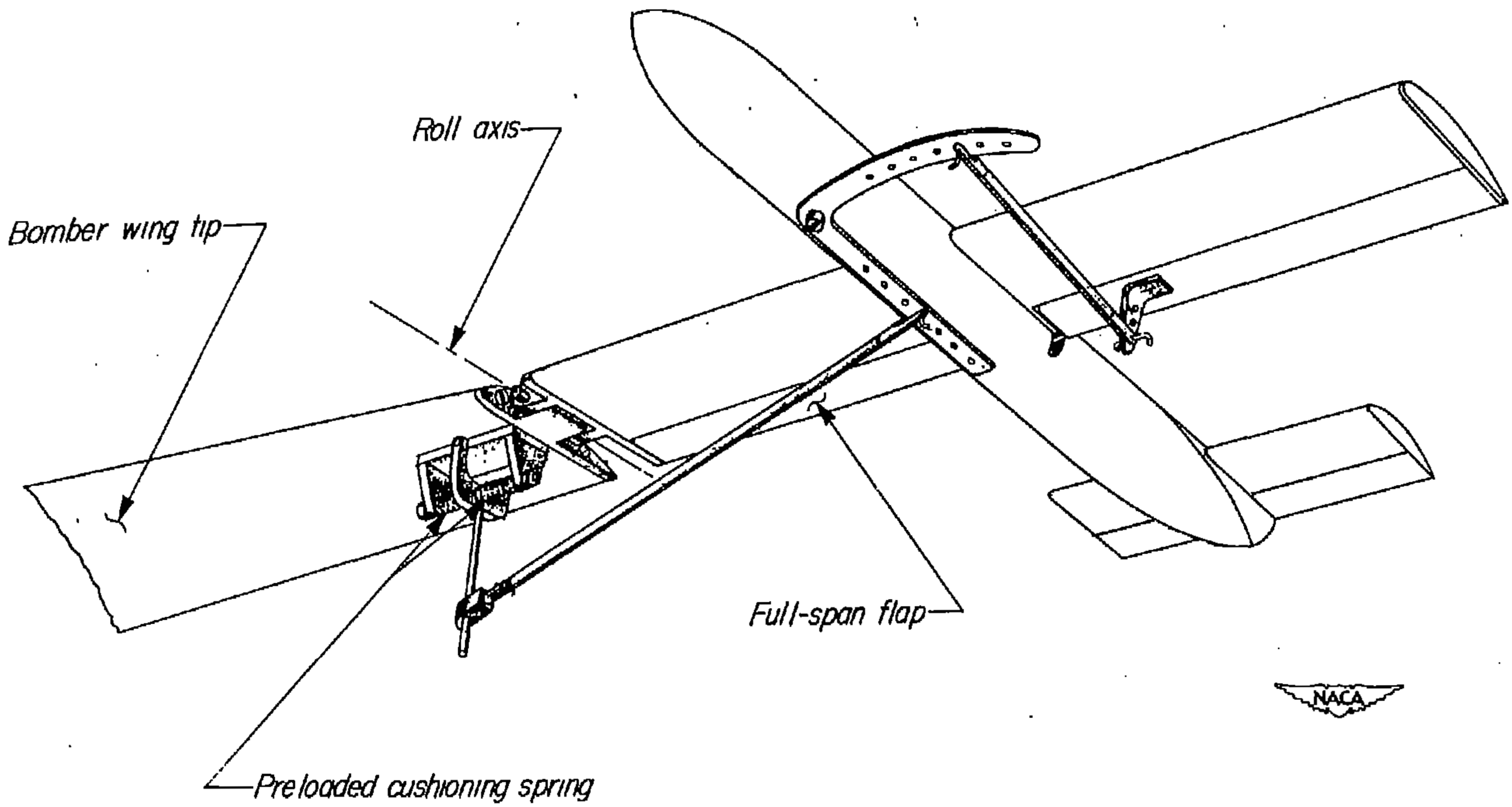


Figure 2.- Sketch of linkage system used to deflect full-span flaps of free-floating tank in response to the relative angle of bank of the tank with respect to the bomber.

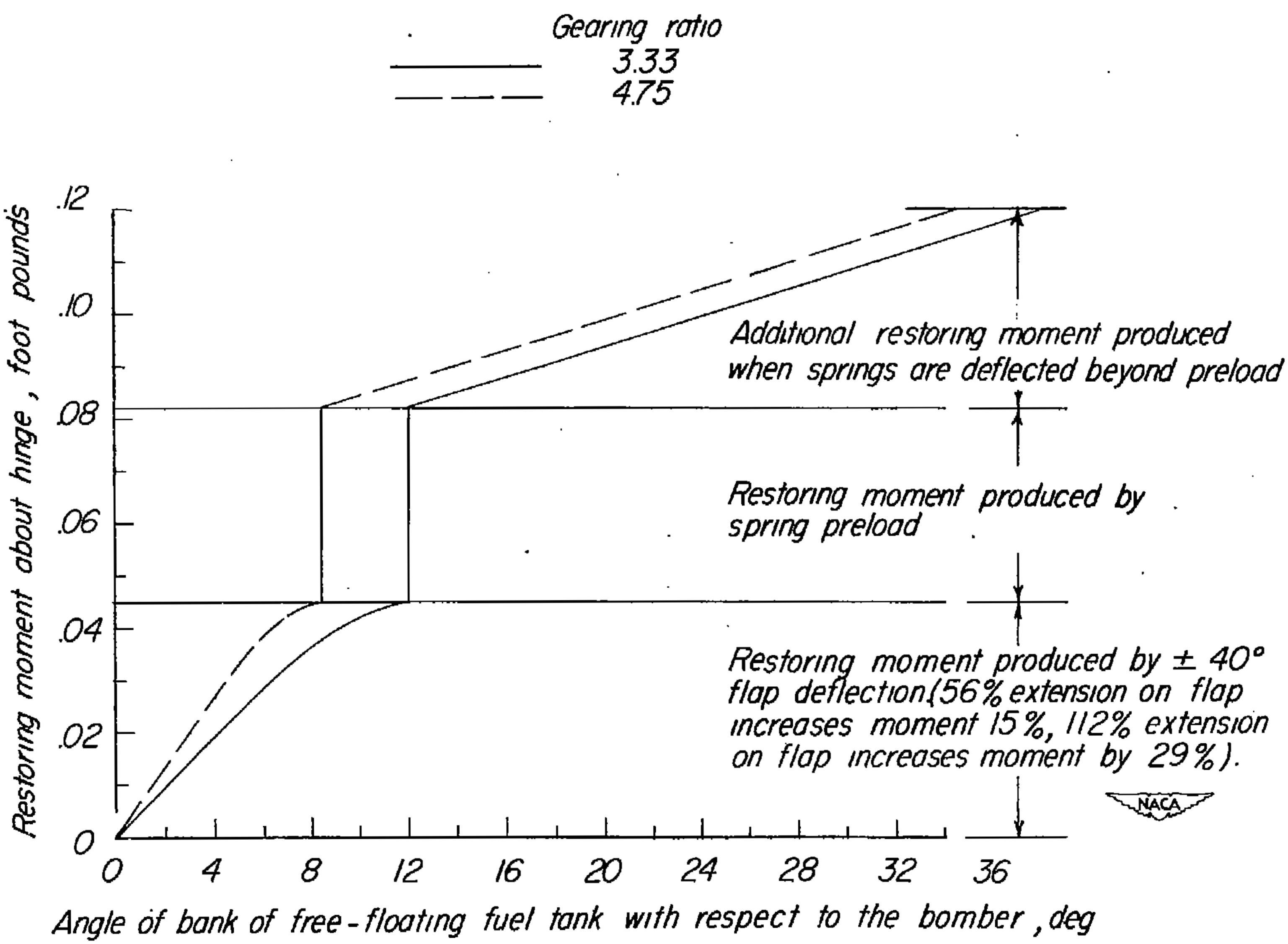


Figure 3.- Variation of applied restoring moment with angle of bank of free-floating fuel tank with respect to bomber.

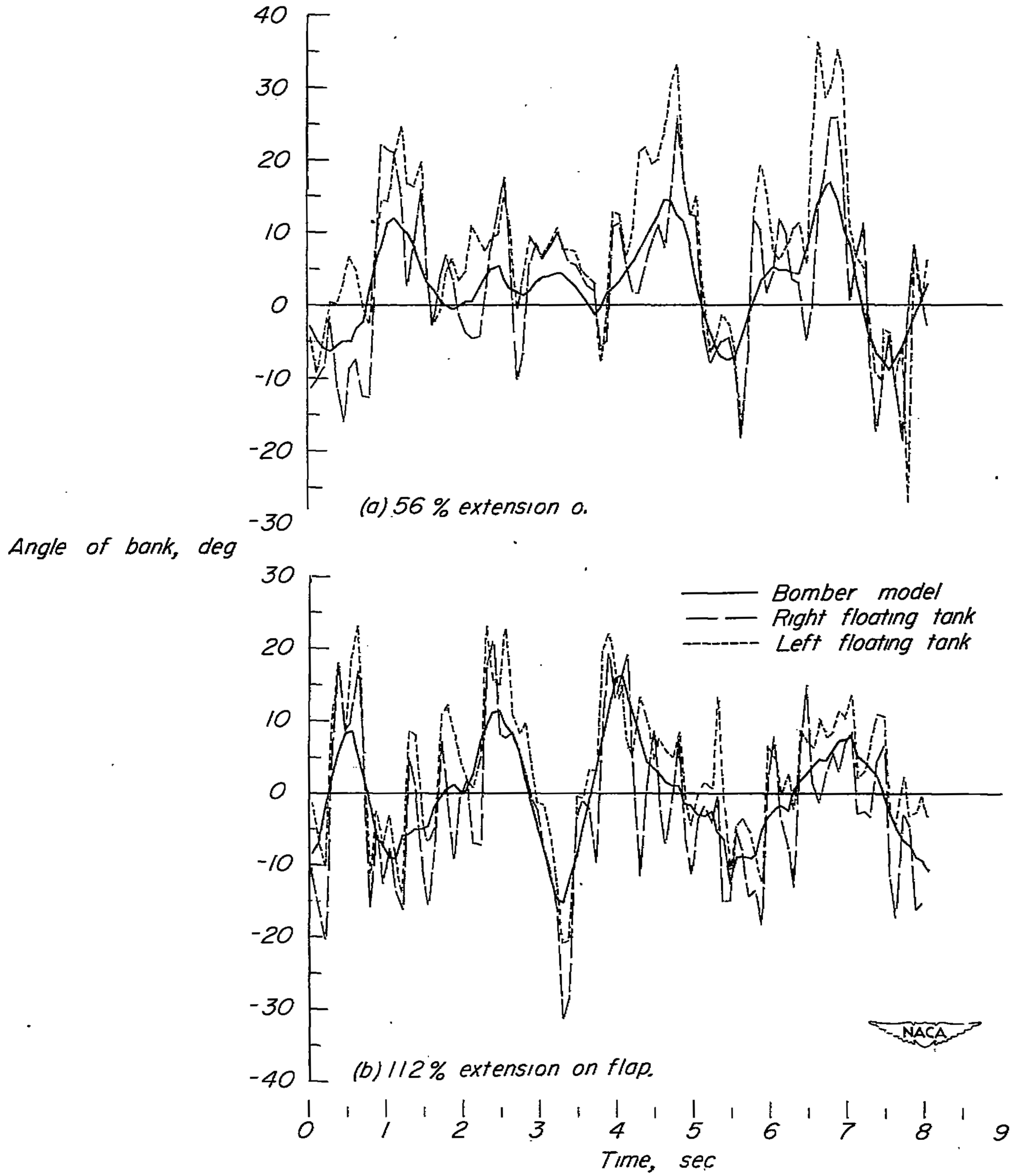


Figure 4.- Rolling motions of bomber and free-floating fuel tanks. Gearing ratio, 3.33.

[redacted]

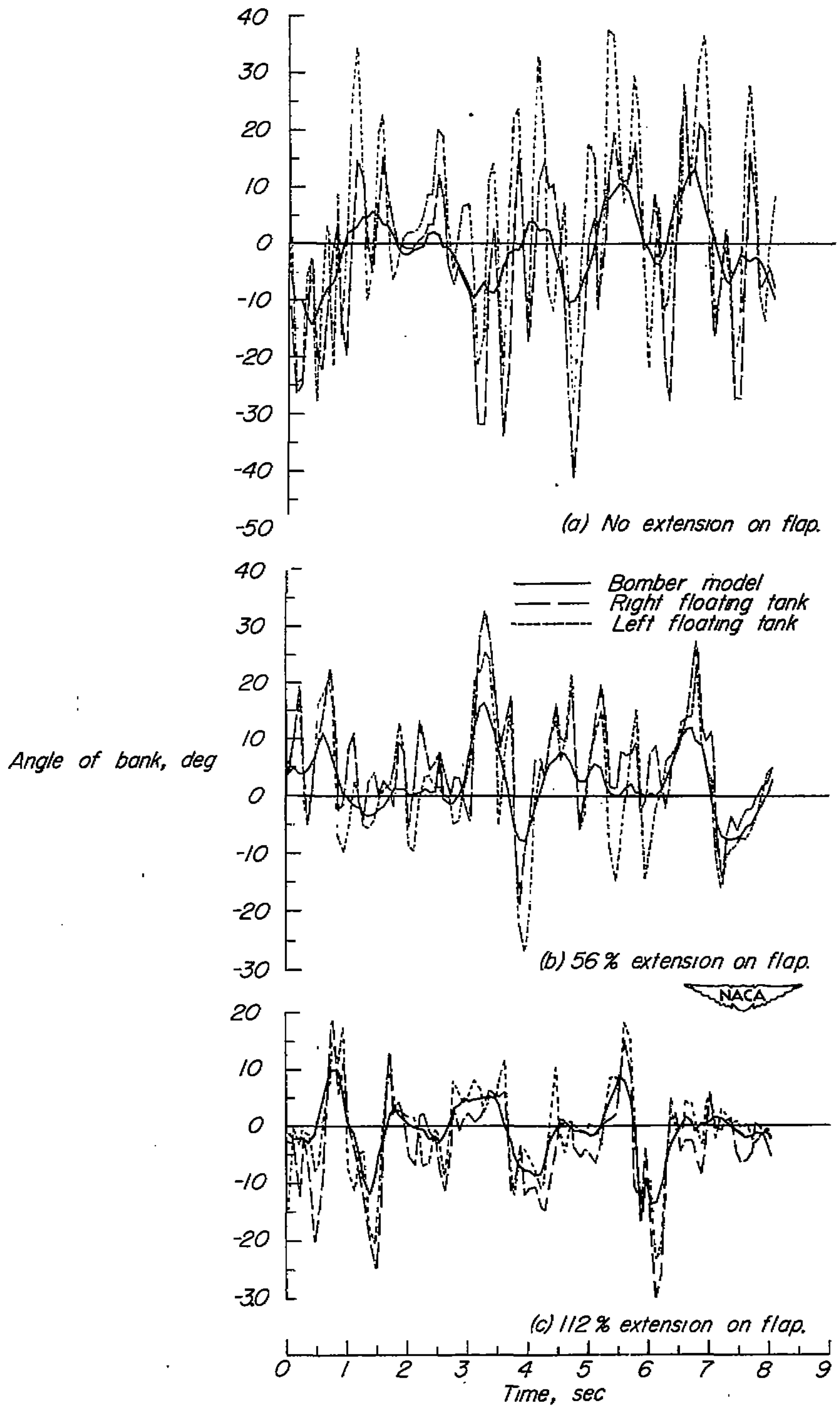


Figure 5.- Rolling motions of bomber and free-floating fuel tanks. Gearing ratio, 4.75.



NACA-Langley - 8-7-51 - 275

[redacted]